To continue to burn something? : Technological, economic and political path dependencies in district heating in Helsinki, Finland

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Abstract

The transition away from fossil fuel based infrastructure for heating and cooling has to happen on a scale and timetable with no historical precedent. As the systems are large and networked, path-dependencies constrain the transition that is further complicated by the diversity of stakeholders. Here we analyse the case of transitioning the district heating system in the city of Helsinki, Finland, within the target of a carbon neutral metropolitan area. Despite relatively advanced climate policies, path-dependencies on the political, technological-material and economical levels interact in creating a ”wicked” problem with no obvious solution and potential for backsliding. It is in this context that a possibility of a green paradox arises: despite the explicit commitment of all stakeholders towards carbon dioxide emission reductions, the combination of the path-dependencies may result in a transition that increases emissions. Our results highlight policy implications of path-dependencies for researchers, government and business.

Keywords

path-dependency; energy transition; district heat; green paradox

Declarations of interest

None

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1 Introduction

Transition to low-carbon infrastructure is a key target for economies aiming to mitigate the worst effects of climate change and to achieve the goals of the Paris agreement 2015. The literature on transition emphasizes the need for a deep-seated and wide-ranging transition within three decades [1], [2], [3], while acknowledging that the combination of the needed scale and pace of change has no historical precedent [4], [5].

From the perspective of material and energetic conditions of societies, the crucial question is the legacy infrastructure that has been built, maintained and is still run mostly on fossil fuels [6], [7]. The infrastructure includes power plants, energy transmission and storage systems, buildings, transport systems, and city structures, which in Smil's [7] estimate correspond to at least 25 trillion USD (1990 international dollars) in investments during the last century alone.

Replacement, early retirement or retrofit of existing infrastructure is constrained by economic, political and technical factors with their own historical trajectories. The interlinked path-dependencies make the problem complicated. There is a diversity of stakeholders, and decisions made now will result in lock-in of development paths and resources for potentially several decades, while every year of inaction necessitates even faster cuts of emissions in the future. Responding to these problems implies using systemic knowledge about the interactions of stocks and resource use at different spatial and temporal scales [8].

Here we build on the existing literature of path-dependencies and connect it with the literature on transitions. We then use this general context to frame one recent case in Finland as illustrative of the real-world path-dependencies and their effect on climate action: the role of the district heating (DH) system in the city of Helsinki in the overall goal of carbon neutrality nationally and in the Helsinki metropolitan area.

In the literature, energy transition is analyzed from different perspectives, such as social, technological, economical, infrastructural, institutional and political. The so-called multi-level perspective [9], [10], analyses transitions arising from the interplay at three analytical levels: “niches (the locus of radical innovations), socio-technical regimes (the locus of established practices and associated rules that enable and constrain incumbent actors in relation to existing systems), and an exogenous socio-technical landscape” [9]. Here we concentrate on the level of socio-technical regimes as the level where the analyzed constraints and path-dependencies appear, and the analysis will concern the technological, economical and political perspectives. The “wickedness” [11] of the problem of transition is illustrated by the possibility that despite the explicit commitment to the goal of carbon neutrality by all relevant stakeholders, the current trajectory for the system may lead to a “Green Paradox” [12]: due to efforts towards transition, the actual amount of greenhouse gas (GHG) emissions may increase.

Overall, the purpose of this study is to show how path-dependencies interact in creating a complicated problem for energy transition with no obvious solution and even potential for backsliding. Furthermore, our analysis offers guidance on how policies may be changed so that the green paradox can be avoided.

In this case study our research questions are:

1. What are the key path dependencies, constraints and legacy technological solutions in DH in Helsinki, as framed by the need to move to carbon neutral energy provision?
2. How do these path-dependencies underlie the wickedness of the problem of transition towards carbon neutral energy, and even point toward a trajectory creating a green paradox?
3. What general lessons for policy guidance can be derived from this case study?

2 Background: Energy transitions, lock-ins, path-dependency and the green paradox

It is abundantly clear that there is a need for massive shift in the way energy is generated and used. While there is a constant barrage of news about breakthroughs of renewable energy in the markets, and their cost is starting to be competitive [13], past experience of energy transitions is worth observing. Historically, transitions have been slow, and the evolution of technologies is influenced by problems of scale and previous infrastructure [6], [7].

Recently, Sovacool [4] suggested that the present transition might be proceeding quicker than historical examples. The conventional transition literature, e.g., [14], [7], posits that it takes between 50 and 160 years for a total energy transition to occur. Sovacool [4] suggests that future energy transitions can be accelerated to the point where they take only a few years or decades. On the other hand, Smil [7] and Fouquet [15] argue that scaling issues and legacies from previous technology point to a more conservative estimate. Smil [7] offers a critique of Sovacool's [4] suggestion, citing evidence suggesting that at a national level transition can be fast, but on the global level it is much slower. The slow pace is mainly due to path-dependency and technological lock-ins.

Fouquet [15] offers a review of energy path-dependency and lock-in situations. A lock-in situation is usually referred to when energy generation is preferential to using a system that is either less energy-efficient or is highly energy-intensive compared to best available current technologies. Lock-ins happen when there are high infrastructure costs or there exist legacies of previous infrastructure that would be expensive to change or retrofit. They can also happen through historical trajectories where early-on competition has pushed an energy system towards one particular technology, which in turn has increased its likelihood of becoming the dominant technology [16], [15]. There is a wide literature on this issue, usually under the title “history matters” [17], [18], [19].

Lock-ins and path-dependencies are not only a matter of infrastructure and technology, but may also arise due to policy decisions. For example, the “green paradox” is an example of adverse policy fueled path-dependency. The concept was coined to illustrate a situation where the announcement of a future climate policy, such as a carbon tax, raises short-term emissions as fossil fuel producers increase their extraction today as a response to an anticipated reduction in future resource rents [20], [21], [12]. Other examples of green paradox include the observations that subsidies for renewable energy can increase emissions through increasing fossil fuel extraction [22] and that giving positive feedback to citizens on their green choices can lead to less green behavior by the same citizens [23]. Following [12], we will use the term in a wide sense to describe unintended negative (for instance, emission increasing) consequences of climate policies.

Harjanne & Korhonen [24] have pointed out how the use of the term “renewable energy” to cover a wide variety of very different forms of energy generation is problematic in discussions of transition. They note that the term contains problems with regard to sustainability, incoherence, policy impacts, and bait-and-switch tactics [24]. As an example of the bait-and-switch tactic, Harjanne & Korhonen [24] discuss the national coal ban in Finland, which is communicated as an accelerated action for climate change mitigation [25]. However, the expected outcome is a move towards wood biomass use [26], a renewable source, which, however, produces more end-of-pipe emissions compared to coal.

In the current international GHG accounting framework, based on the Kyoto protocol and implemented in the EU Emissions Trading System (ETS), bioenergy is treated as carbon neutral in the energy sector, and any emissions from bioenergy are included in the land sector (LULUCF) accounting. Furthermore, the EU has labeled wood biomass as a renewable energy source [27]. Consequently, fossil fuels are being replaced by wood biomass around Europe, including in Finland [28]. An additional incentive for the energy use of wood in Finland is provided by the government bioeconomy framework [29], [30], that, for instance, subsidizes wood chip production [31]. The problem is that carbon dioxide emissions per produced energy unit are higher from wood biomass than from coal, and the uptake of the “carbon debt” resulting from wood burning is conditional on the dynamics of biomass (re)growth [32]. Consequently, the climate benefits of transitioning from fossil fuels to wood have been contested on the global and European levels [32], [33], [34], [35], as well as in the context of the Finnish bioeconomy framework [36].

The life-cycle comparison between coal burning and wood biomass burning contains many variables, including combustion and processing efficiency, carbon intensity of combustion and carbon intensity of supply chain for both fuels, as well as the particulars of the forest type and harvesting methodology [32]. Recent research ([32], for studies using Finnish/Scandinavian forest data see [37], [38], [39]) suggests that repaying the resulting carbon debt from the transition from coal to wood takes several decades, even up to a century, which from the perspective of the needed pace of transition may be too slow. These results suggest that transitioning from coal to wood in energy generation may even increase carbon dioxide emissions within the crucial time frame for transition, rather than diminish them.

The coal ban and the implied move to wood biomass form the immediate background of our case study. Our intention is to analyze the path-dependencies and constraints that lie behind the “bait-and-switch” mentioned by Harjanne & Korhonen [24]. More generally, we use Helsinki district heating system as a case study on how a well-meaning and advanced climate policy can have adverse effects due to not taking fully into account the path-dependencies on various levels, including the material, economical and policy levels. In our analysis, it is the interaction of the path-dependencies on these levels that creates complications for the transition and the potential for a green paradox. Furthermore, we will use the analysis of the path-dependencies in order to evaluate the policy implications of the case.

The potential for the green paradox is set by the path-dependent structure of the existing DH system. It is technically built and optimized for a certain temperature and pressure, and needs a wide enough customer base to make economic sense. Under these circumstances, if the decision of replacing existing co-generation plants happens in a moment where emissions from coal are penalized or coal use is outright banned, and emissions from biomass are not, the result may be investment in a fleet of biomass burning plants that lock in years if not decades of increased emissions, even though the explicit goal at the moment of decision is to decrease emissions.

Next, in section 3, the methods and data are described. In section 4, the object of our case study, the city of Helsinki district heating system is introduced from the perspective of its historical trajectory, and its main stakeholders. In section 5, the existing situation is briefly described from technical, economical and political perspectives before, in section 6, analyzing the material and policy-related path-dependencies, and showing how they interact in creating a complicated situation with a clear potential for a green paradox. The results are presented in section 7, before a discussion in section 8 and conclusion in section 9.

3 Methods and data

Our approach is exploratory and aims at description and understanding of a case within a larger context [40]. We set out for inductive fact finding without any theoretical preconceptions or hypotheses to test, like in the approaches labeled under grounded theory [41]. The research questions 1-2 are prompted by the problems in transition to low-carbon infrastructure, as articulated by multiple stakeholders. The questions are motivated by the need to find out which factors are stalling transition in the particular case, and the context for the questions is formed by the existing literature on transition and path-dependencies. They also lead directly to research question 3, as a better understanding of the path-dependencies may inform the practices of the different stakeholders.

The research setting is thus case-led rather than theory-led, and consequently the data gathering relies on methods (document analysis, participant observation) suited for exploratory contexts with low theoretical ambitions [42]. By definition, results from this kind of inductive and exploratory research setting cannot, as such, distinguish between existing theoretical views and the verification of the results is hard if not impossible. However, the results may be hypothesis confirming or hypothesis generating, like results from grounded theory approaches, which as [43] notes, have been fruitfully used for various topics in energy research.

For original data gathering, we used document analysis and participant observation. Document analysis refers to the process of collecting data via analyzing written documents [44]. The original data on the research questions 1-2 was gathered primarily through analysis of publicly available documents published by the stakeholders. A comprehensive list of the documents used is presented in the supplementary material. It contains the websites of the included stakeholders (national and local administration, the utility company, political parties, NGOs and research organizations), as well as documents from newspapers, web publications and social media. The documents were read, and notes taken on the views presented on the future of DH, the coal ban, use of wood biomass and other relevant issues. The analysis was conducted manually, as it was seen that, e.g., quantitative coding or statistical methods were not needed. Documents were read and notes taken by multiple authors, and the main author independently verified from original sources the views presented here. The main document sources that are available online are referenced within this article.

Participant observation is often used in long-term studies intended for intensive involvement with a group of people, but it can also be used for data-gathering without the goal of deep anthropological or cultural study [45], [46]. Participant observation is recommended for research settings where researchers need to enrich their understanding of what questions to ask and for gaining an understanding of the meaning and relevance of the data [46]. In this case, participant observation was chosen as a method to facilitate direct contact with stakeholders in order to validate the data gathered from document review and to widen the range of what to look for in the data.

The authors conducted the observation either as complete participants or as participants-as-observers [45] in 14 different events and discussions on the theme of transition in DH in the Helsinki metropolitan area within the timeframe between September 2018 - January 2019. As the time period was limited and researchers from various universities and research groups were and have been involved in the discussions on transition for a long time in visible roles, the potential ethical dilemmas of participant involvement [47] could be kept to a minimum. The events ranged from private discussions and invite-only round-table discussions with less than 10 participants to large public events (see table 1). Representatives from all the analyzed stakeholder groups were present at the same time in at least three of these events, while participants in some of the events consisted only of one group of stakeholders.

Event	Topic	Date	Participant stakeholders
Public seminar	Alternatives to coal in DH	26.9. 2018	Greenpeace Finland, political parties
Private discussion	Technical and economic issues, esp. load and production curves	10.10. 2018	ex-CEO of Helen Ltd
Private discussion	Political issues, views within the city council	26.10. 2018	City councillor (Greens)
Private discussion	Technical and economic issues	2.11. 2018	ex-CEO of Helen Ltd
Private discussion	Technical and economic issues	14.11. 2018	ex-CEO of Helen Ltd
Roundtable discussion	Upcoming motions on DH in the city council	20.11. 2018	City councillor (Greens), city councillor (Pirate Party), city councillor (Left Alliance)
Private discussion	Technical and economic issues	27.11. 2018	ex-CEO of Helen Ltd
Private discussion	City ownership policy	4.12. 2018	Chairman of the Board, Helen Ltd
Public seminar	Roadmap towards carbon neutral DH in Helsinki	11.12. 2018	Representatives from city council groups, Helen Ltd., NGOs
Private discussion	Political issues, views within the city council	11.12. 2018	City councillor (Social Democrats)
Private discussion	Coal ban and DH	12.12. 2018	City council group, Greens
Roundtable discussion	Coal ban and DH	20.12. 2018	Representatives of Greenpeace Finland, FinGo, and The Finnish

			Association for Nature Conservancy
Roundtable discussion	Helen Ltd. existing and future technological plans	20.12. 2018	Representatives of Helen Ltd.
Invite-only researcher meeting	Discussion on the ”Clean district heating – how can it work?” report	7.1. 2019	Representatives of Helen Ltd., NGOs

Table 1. Events of participant observation. Location for all events in Helsinki, Finland.

The authors participated in the events (all more than once, and none in all of them) and took notes on their observations. The notes were collected and reviewed by multiple authors. As the goal was to find data on views that stakeholders explicitly hold and are willing to express, note-taking was limited to factual statements presented by the participants. For clarity and brevity, the findings from observations are reported in the article text without referring to particular events or notes. When the article relies on notes from spoken communications within the events, the correctness of the presentation has been confirmed with the relevant stakeholder(s) through subsequent direct communications (e-mail and phone) conducted during February-March 2019.

4 District heating infrastructure in the city of Helsinki

4.1 Infrastructure

After WWII, Finland launched a program of reconstruction with rapid increase in energy generation [48]. These efforts, among other factors, brought into focus the need to improve primary energy efficiency and minimize fuel imports, leading to the adoption of DH [49]. The energy efficiency of energy generation from burning can be substantially increased in combined heat and power (CHP) units, and the DH network, in addition, contributes to improved total energy system efficiency [50]. Consequently, the efficiency of cogeneration is a key rationale and design constraint for the evolution of the DH system in Helsinki, setting a path-dependency right from the start. Helsinki had some city-block sized and smaller cogeneration units based on burning wood and coal already before the war [51]. However, in the decades after the war, the larger cogeneration plants were designed exclusively for coal burning, which constrains the temperature and pressure of the heat transmission liquid [49], which, in turn, determines, in part, network characteristics and parameters for customer equipment.

Altogether five big cogeneration plants have been built in Helsinki since the 1950's (see Table 2 and Figure 1). The post-war demand for electricity was first met in 1953 by building the Salmisaari A power plant which uses a coal-powered turbine for electricity generation, and from 1957 on, the excess heat from the unit is captured and used for district heating. In 1960, 1974 and 1984 new coal cogeneration plants are built (Hanasaari A and B, Salmisaari B). The first CHP plant using natural gas (Vuosaari A) is taken online in 1991 and a second in 1998 (Vuosaari B) [52].

Currently, Hanasaari A has been decommissioned, and Salmisaari A is a reserve unit, with Salmisaari B (electricity capacity 160 MW, heat capacity 300 MW), Hanasaari B (electricity capacity 220 MW, heat capacity 420 MW) and Vuosaari (electricity capacity 650 MW, heat capacity 600 MW) functioning as base load units [53]. In addition, the DH network has seven smaller heating plants around the city area with a total heat power of 2200 MW and a heat-only boiler in Salmisaari, with 170 MW of capacity [54]. Over half of the yearly heat generation is done by burning coal (with heat generation capacity from coal at 890 MW), the rest being a combination of natural gas (ca. 30 %), heat pumps (using excess heat from waste water as a source, ca. 10%), wood biomass and heavy oil [55].

Power plant	Main fuel	Commissioned	Decommissioned	Current role	Heat capacity
Salmisaari A	Coal	1950	?	Reserve	170 MW
Hanasaari A	Coal	1960	2007	-	-
Hanasaari B	Coal	1974	Planned 2024	Base load	420 MW
Salmisaari B	Coal	1981	?	Base load	300 MW
Vuosaari A	Natural gas	1991	?	Base load	165 MW
Vuosaari B	Natural gas	1998	?	Base load	430 MW

Table 2. Helen Ltd. power plants.

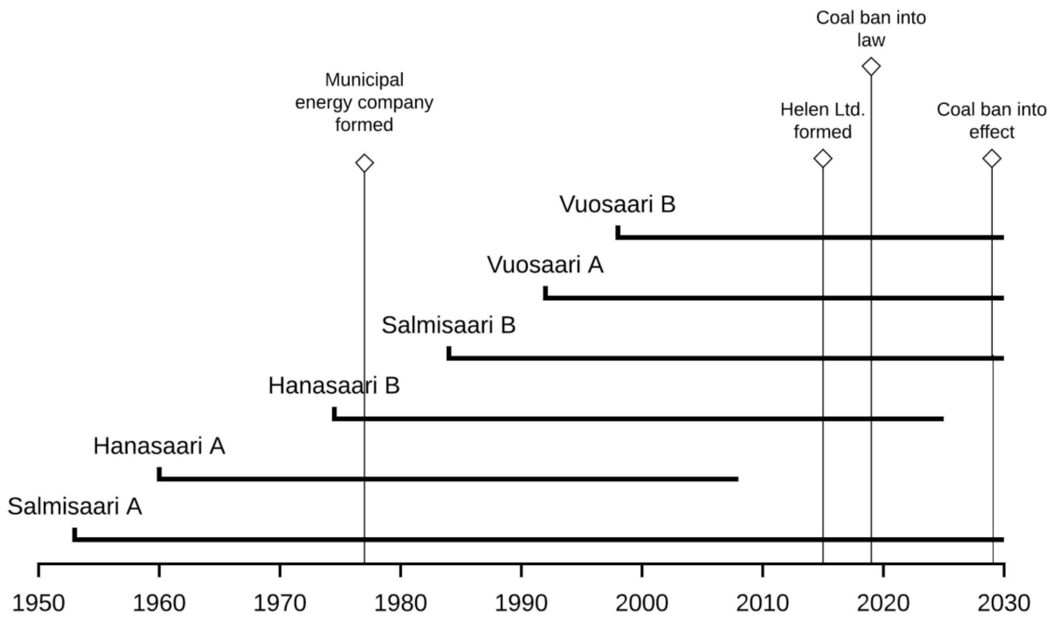

Figure 1. Timeline of Helen Ltd. power plants and main historical events 1950-2030.

In 2017, the district heating network comprised ca. 1300 kilometers and provided heat for ca. 90% of the built cubic volume in Helsinki. The company sold 6 606 GWh of DH to 15 289 connections, and the connection power (maximum load) was 3 400 MW [55].

The basis for the current utility company is formed in 1977, when the municipal electricity company and the municipal gas company are combined into the municipal energy company [52]. In 2015 the municipal company is transformed into a private enterprise (Helen Ltd.), with the City of Helsinki as the sole owner [52] (see Figure 1). Currently, the main business sectors of the company are district heating, district cooling and electricity [52]. In the following, we will concentrate on DH, only touching on electricity and district cooling when they relevantly affect the DH transition. In 2017, the company generated a profit of 81 million euros, with a turnover of 805 million [55].

4.2 Stakeholders

The stakeholders in the question of DH as a part of energy transition can be identified in different ways. Ultimately, as the issue of GHG emissions affects all life on the planet, the stakeholders involve all humans. More directly, the stakeholders include at least the utility company, its owners and customers, the citizens of the city and the whole metropolitan area, the national government and citizens of Finland, various NGOs and political organizations, researchers, fuel and technology suppliers, and the wider energy sector and its institutions. We will here concentrate on three stakeholders or stakeholder groups: the utility company, the city and NGOs/political organizations, and touch on the national level as a regulatory actor. We believe that the viewpoints presented by these three groups are sufficient to illustrate how the path-dependencies end up hampering intended climate action.

The main actor is the utility company that owns and runs the DH system. Its views are publicly available on its own website, where it presents both official information and more free-form audience-engaging content such as blog posts. The views of the utility company are also a point of public interest, so that its representatives are often interviewed both for journalistic and research purposes (e.g., [36]).

The city of Helsinki has a dual stakeholdership: on the one hand it is the owner of the utility company, on the other hand it is a regulator determining policy. Ultimately, the city of Helsinki consists of its citizens that are represented by an elected city council overseeing the executive and regulatory affairs of the city. All major policy changes both with regard to the utility company and climate and energy policy have to pass through the council. The views of the council itself are a matter of public record [56], and its members representing various political parties have their own publications, e.g., on the internet.

There is a number of NGOs and NGO-led campaigns advocating ambitious climate action, in general, and active in the discussions around DH, in particular. Three of these, Greenpeace Finland, The Finnish Association for Nature Conservation (Suomen Luonnonsuojeluliitto) and FINGO (a NGO platform for global development), have dedicated staff on climate and/or forest issues, have published position papers on climate and forest issues [57], [58], [59] and have regularly taken part in the discussion on DH. Their views are therefore analysed, below.

5 Economical, Technical and Political Operating Environment

5.1 Economical

Economically, the role of the company is to generate revenue for the owner, within the corporate governance guidelines set by the city [60]. Although the DH network is in its area of coverage something of a natural monopoly, at the edges of the network the company faces competition from other smaller providers that offer decentralized heating, e.g., via heat pumps with geothermal wells and ambient air as heat sources. In the densely built city center the monopoly is relatively secure, as alternative modes of heating are either technically not viable (for instance, it is very hard if not impossible to find space for geothermal wells) or much more costly (direct electric heating) [61]. However, investments into energy efficiency, such as insulation and heat pumps, may affect the economic bottom-line also in the city center.

As observed in [50], the total competitiveness of DH is a combination of two cost components: first, the cost difference between centralized and decentralized heat supply and, second, the heat distribution cost. If the amount of heat the company generates and sells diminishes, the proportional weight of the distribution cost in the calculation increases. Thus losing sales and customers via increased energy efficiency or transition to other methods of heating affects the bottom line of a DH provider substantially, as decreases in distribution cost are difficult to obtain. However, densification of urban areas may help keep distribution costs down, and modeling in [50] has indicated that in dense areas reduced heat demand is not a barrier to DH. In addition, it has been observed that taxation of competing forms of heating can increase the competitiveness of DH even in areas of low heat density [62].

In 2018, due to regulatory and political pressure, Helen Ltd. opened its DH network for other providers of heat, for which it pays a seasonally variable rate [63]. For the reason noted above, the open DH network is also a potential problem for the company. Industrial scale CHP units are economically most effective when they are used for base load capacities with uninterrupted uptimes. Consequently, functioning as a network operator promises less economic return than selling heat produced by the company itself. Furthermore, the pricing models are not developed enough for separating the network operator from the heat producers [64]. The company sees that if the share of the heat produced and sold by the company itself via its network plummets, maintaining the DH network and CHP units may lose commercial viability [65].

This network characteristic forms an important economic condition. For instance, network load and temperature adjustments and proactive reacting to weather patterns is best done on the system level (even though the development of smart metering and demand flexibility in so-called 4th generation DH systems may in time change the situation, [61], [64]). Likewise, economically the network needs a large enough customer base. From this perspective, there is a critical threshold for both control over the network and the amount of heat delivered below which the network loses economic competitiveness and loses its advantage in terms of energy efficiency compared to non-networked heat provision.

The basic economic setting is complicated by the fact that the owner, the city of Helsinki, also consists mainly of the customers of the company, the citizens of Helsinki. Helsinki residents are by definition owners of the utility company, and almost always in practice its customers. The majority of the profit generated by the utility company is included in the budget of the city. The budget, in turn, is governed by the city council for the benefit of the residents. The profit also comes out of the pocket of the residents in so far as they generate the revenue for the company by buying electricity and heat (part of the electricity is sold outside of Helsinki). Consequently, the customer price for DH is also partly determined by social factors. If the customers feel that the price is not right, they can vote for representatives that as the owners of the enterprise do have a say on company policies. Here the intertwinement of the economical and the political becomes evident: on one hand the company is statutorily governed to operate as a market actor, on the other hand the owner does set constraints informed by factors other than market prices.

5.2 Material and technological

The company makes agreements with customers, promising to deliver a certain amount of heat. When added together, the sum of these agreements gives the contractual peak load that the company is obliged to be able to provide (in 2018, the maximum contractual load was 3400 MW), even during the coldest periods of the year. Due to seasonal variation, there is considerable difference between the actual peak thermal load and the base load (around 1500 MW) [66].

From the perspective of the plants generating heat, it makes sense to optimize the plant size and location for maximum yearly uptimes according to the base loads. Providing for the peak load, usually necessitated by extended periods of below zero temperatures, creates another important technical constraint. Even though the peak load is required only for a small percentage of the year, it is also the time when customers are most reliant on the service. This necessitates having generating capacity up to double of base loads at the ready for peak periods.

As noted above, the technical and energetic efficiency of the CHP units is best when they have long and uninterrupted uptimes. From this perspective, it makes sense to design the units to correspond to continuous base load use. The existing units have been optimized for cogeneration, and reach high levels of efficiency, up to 90% [66]. In the past few years, they have been readjusted to use a small percentage of wood pellets (up to 10 %) mixed with coal [53].

From the perspective of the network, one crucial factor is the physical location of heat producing units, constrained by the physical location of the most intensive and consistent user loads, supply and return temperatures, as well as city zoning and other regulation on power plant placement. Due to the historical factors discussed in section 3, the network is a so-called high-temperature network, with heat-exchanging temperatures in the hot loop between 65 – 120 °C, and during cold periods 80 – 120°C. The heat exchangers that customers use have been dimensioned for the high-temperature heat exchange liquid.

5.3 Political

The city of Helsinki and the other cities in the Helsinki metropolitan area have committed themselves to carbon neutrality [67]. The city of Helsinki has its own Carbon Neutral Helsinki policy program, with the target of reducing emissions generated within the city by 80 percent and compensating all the rest by 2035 [68]. With regard to this goal, DH is a main concern, as it produces over 40 percent of the yearly emissions of carbon dioxide equivalent GHG gasses [69].

The biggest political groups in the city council for the current term in office (2017-2021) are the Greens and the right-wing National Coalition Party. For the Greens, climate action has been a major goal, and for them the CHP units with their open air coal storage areas and power plant chimneys very visible in the cityscape have been a sore point [70], [71]. The views of the Greens have been supported by NGOs such as Greenpeace, which during 2018 collected a list of over 8000 signatures supporting rapid transition to a coal free Helsinki [72] and published a Gallup poll according to which two thirds of Finns support an end to coal in energy generation by 2025 [73]. Consequently, the 2018 decision [74] by the City Council to explore ways of providing heating without coal and to obligate Helen Ltd. to find ways of providing fossil free DH were presented as important achievement by the Greens [75], [70]. Most of the other groups in the council supported the motion.

As part of its EU climate agreements, Finland has committed to increasing the share of renewable energy sources to 50 percent by the year 2030 [76]. In 2015, the government of PM Juha Sipilä, representing the Centre Party, launched a bioeconomy program, where renewable products based on wood and other biomass, including energy from wood, figure centrally [29]. The bioeconomy program supports even non-renewable peat as a domestic energy source, both for DH and decentralized heating solutions. Toward this goal, the program includes the use of taxation so that peat is more competitive than coal, but more expensive than wood [77]. Major interest groups, such as The Central Union of Agricultural Producers and Forest Owners, which is closely aligned with the Centre Party, are strong supporters of the bioeconomy program and wood biomass as energy source.

The political constraints on DH have been recently brought to limelight with a national ban on coal burning by 2029 [25]. The year is earlier than the economical end-of-cycle for the existing CHP plants (estimated to be in the mid-2030's). The Centre Party has presented the coal ban as the major climate action accomplishment by the government of PM Sipilä, with his Centre Party colleague Kimmo Tiilikainen as the Minister for Environment [78]. The other parties in government, the National Coalition and Blue Reform, supported the ban, as do majorities in the opposition parties.

Concern over and opposition to the ban did not follow party lines. The opponents and skeptics that represent almost all of the major parties, have raised three kinds of concerns [79]. First, there are concerns over the effects on DH prices and the competitiveness of the companies. Second, opponents of the ban pointed out that, for instance, the Helsinki power plants can convert over ninety percent of the fuel energy into electricity and heat, while coal burning plants in Europe often operate on energy efficiency that is much lower, down to 40%. This means that when the more effective coal burning plants are scrapped and their emission allowances released, carbon dioxide emissions in the EU may rise. Of course, this green paradox can be avoided if the state or another actor buys the released allowances, as suggested, for instance, by Helen Ltd. and The Finnish Innovation Fund Sitra [80], [81]. The third concern, one to which we will return below, is that given the current availability and pricing of heat sources, the most likely replacement for coal is biomass, with problems of its own.

The analyzed environmental NGOs (Greenpeace, The Finnish Association for Nature Conservation and FINGO) recognize the possibility of a “green paradox” due to the coal ban and move to wood biomass. However, in their view the coal ban is necessary for a variety of reasons. First, it is needed as a factor that forces the utility company to “do at least something".[1] The NGOs have been frustrated by what they perceive as foot-dragging by the utility company. In their view, the company has been aware of the need to transition away from fossil fuels for three decades but has done little and found excuses for continuing coal burning. Second, the coal ban is needed as a signal of ambitious work against climate change. The argument goes that a developed country like Finland can help international efforts by setting an example. Third, the NGOs emphasize the role of research and development. Even if at the moment there is no realistic scenario for providing for the peak load with non-burning heat sources, new technologies can advance rapidly. Thus the representatives of the NGOs see that the utility company should launch ambitious R&D efforts, preferably in an open manner that could involve a wider community. Furthermore, the NGOs see that the coal ban is just one step on a long road. The issue of emissions (and other potential ecological damage, such as biodiversity loss) from burning wood biomass can and should, in their view, be tackled separately.

From the perspective of the city, the possible increase in emissions is a more troubling issue, even though it, like the utility company, may under the current regulatory regime report diminishing emissions when transitioning from coal to wood. The city mayor, Jan Vapaavuori representing the National Coalition Party, has repeatedly maintained that economically the utilization of biomass benefits mainly other areas in Finland, and is not the best solution for the city, either economically or ecologically [82]. The city would prefer that Helen Ltd. runs the DH network on non-burning base load technologies. However, the city also requires that the company has to be competitive. In the current technological landscape, the company can not fulfill both demands from its owner at once.

1 The views summarised in this paragraph are gathered through participant observation, and their validity confirmed in subsequent communication. See section 3.

6 Path dependency and its role in complicating transition

Given the political goal of carbon neutrality and the ban on coal use, the most urgent challenge for the DH system, and its operator, Helen Ltd., is replacing the existing coal-powered CHP plants, Salmisaari B and Hanasaari B, with total heat capacity of 870 MW. Even though natural gas produces much less carbon dioxide than coal, also the natural gas powered plants Vuosaari A and B will need either replacement or carbon capture technology to become carbon neutral. In addition, natural gas is more expensive than coal and Finnish energy companies see low security of supply (with Russia as the only provider) as a barrier for increasing the role of natural gas [83]. The timeline of the coal ban, 2029, means that if scrapped, the plants will not reach the end of their planned lifecycle. As the company loses not only the heat generation from these plants but also the electricity generation, it loses some of its revenue and, consequently, means of investment.

Currently, according to the utility company itself and confirmed by studies by research organizations, no economically competitive non-burning technology exists that could provide the needed amount of heat load for the peak periods [84], [61]. This is also the view held by city officials [85]. The only possible alternative would be the utilization of direct electricity-to-heat boilers [61] but this alternative presupposes a massive increase in electricity availability and grid upgrades – matters that are not in the hands of the utility company. If the transition would happen in terms of boilers used within individual houses or blocks, a big part of the rationale for DH network would disappear. On the other hand, done in a centralized manner, the move to electricity-to-heat might use the DH network as a regulator of intermittent electricity generation. However, due to the technological constraints mentioned above, these options are not on the table. As the CEO of Helen Ltd., Pekka Manninen, has pointed out, this means that the decision over which technology replaces coal burning depends on when the decision is made: in the future new non-burning alternatives, such as small modular nuclear reactors, may become available, but with currently available technology, the transition will result in wood biomass burning [86].

The utility company emphasizes that it has to operate within the current regulatory and contractual framework. Given the need to provide for the peak load and to operate with an acceptable profit margin, providing heat through burning is the best option for the company. As head of corporate responsibility for Helen Ltd., Maiju Westergren, puts it: “The fastest route away from coal and fossil fuels is via biofuels and via accepting the fact that we continue to burn something” [87]. With the end of coal use on the horizon, market conditions suggest biomass as fuel, as also pointed out by independent research [84]. In sum, the choice that fits the existing legacy parameters is to burn biomass instead of fossil fuel in the base load units that need to be constructed to replace the existing CHP units.

As noted above, there is a list of concerns about the trajectory of replacing coal burning with biomass burning. These concerns are voiced, for instance, in the statements on the coal plan that stakeholders have left in the official governmental service collecting statements on new legislation [79]. The concerns with regard to a move to biomass expressed, for instance, by Helen Ltd. and other energy companies, include questions of availability, price, GHG emissions, small particle emissions, logistics and effects on biodiversity and other ecological effects.

The official evaluation on the coal ban legislation concludes, based on a review of the views of current coal users, that the most likely outcome of the ban is that coal is replaced by wood biomass [26]. More strikingly, the evaluation also states that because of this replacement the ban will not likely reduce Finnish carbon dioxide emissions [26]. The statement is quite stunning, when we remember that the legislation is intended and celebrated as a major climate action. However, there is no reason to suspect its validity. As Sterman et al. [32] observe, while the combustion effect of wood pellets is lower than coal and the wood supply chain has higher procession emissions, “wood-fired power plants generate more CO2 per kWh than coal.”

With regard to the main goal of the transition, reducing GHG emissions in the name of climate action, the result of this path of least resistance is paradoxical. However, the increase in carbon dioxide emissions would be politically acceptable, since current GHG accounting in the EU includes wood felling in the LULUCF sector, and biofuels are deemed to be carbon-neutral [27]. Thus, even if the physical end-of-pipe emissions compared to coal burning increase, in the current regulatory framework the emissions are not penalized. This situation is, of course, not particular to Helsinki or even Finland; rather the accounting of LULUCF sector emissions, especially biomass burning, is a contentious issue worldwide [88], and researchers have warned that the new European Union renewable energy directive (RED), aimed at reaching higher renewable energy targets, could result in a situation where energy generation “consume[s] quantities of wood equal to all Europe’s wood harvests, greatly increase[s] carbon in the air for decades, and set[s] a dangerous global example.” [34].

The outcome is also closely linked to the use of the term “renewable”. As Harjanne & Korhonen [24] point out, the term “renewable” contains many ambiguities and is therefore a poor indicator for successful energy policy. In this case, energy from burning wood biomass is renewable, but not emissionless and not, without further qualifications, sustainable. Most damagingly, the concept enables bait-and switch schemes that seem to address climate change, but in reality serve other interests [24]. In the case of Helsinki DH, these interests include the economical goal of forest owners and bionenergy providers to have lucrative markets and the interest of politicians to promote domestic renewable energy. These interests combined with the economic and technical path-dependency according to which "to burn something" is the most competitive available technology, are on the trajectory of locking in yet another decades long increase in carbon dioxide emissions from DH.

This potential new lock-in also introduces a new risk. It is possible that the international GHG accounting regulations and ETS are changed over time, so that the end-of-pipe emissions of wood burning have an economic effect, for instance, through inclusion in the ETS or through a price on natural carbon sinks, in which case wood biomass price is bound to increase. These worries have registered within the stakeholders, as, for instance, the chairman of the board for Helen Ltd., Osmo Soininvaara, representing the Green Party, has predicted that by 2030 at least a part of wood burning emissions will be included in the ETS [89].

7 Results

The first research question was to identify the key path dependencies, constraints and legacy technological solutions in DH in Helsinki, given the goal of rapid transition. In view of the above, the path dependencies and constraints can be listed as follows:

- The company is committed and contractually bound (economic constraint)
- to reliable service (socio-economic path-dependence)
- during peak load periods (material constraint).
- This together with the high-temperature nature (material path-dependence) of the network means that no non-burning technology currently exists to replace coal.
- In current GHG accounting frameworks, emissions from wood burning are calculated on the LULUCF sector (political path-dependency), which means that from the

emission accounting perspective, the move from coal to wood is possible.

- In addition, the bioeconomy framework of the current government supports wood biomass by subsidies and taxation (political constraint) and
- coal use in energy generation is banned by 2029 (political constraint).

The second research question concerned the role of these path-dependencies in complicating the transition towards carbon-free energy. Due to the material path-dependency, government supported market environment and regulatory framework, the trajectory for DH in Helsinki produces a green paradox if coal is replaced by wood biomass: even if all stakeholders are committed to reducing GHG emissions and act on their commitment, physical emissions may grow. Moreover, this green paradox may be enforced by a future lock-in. For the utility company and its owner, investments into heat producing units are long-term affairs, with pay-back times extending well over a decade. Thus investing, for instance, in wood biomass burning base load units means, other things being equal, that biomass will be burned for decades, so that the increase in carbon dioxide emissions is perpetuated.

This is the crux of the path-dependent nature of the green paradox at hand. The need (and, from the company's contractual and commercial perspectives, responsibility) to do long-term investments in industrial-scale infrastructure locks in future emissions for decades. If the decision happens at a moment when coal emissions are penalized but biomass emissions are not, the result may be an increase in emissions even though the explicitly expressed reason for infrastructure overhaul is to decrease emissions.

The third research question was the policy implications to be drawn form the case. As noted above, coal emissions from energy use are included in the ETS, while wood biomass emissions are included in the accounting of the LULUCF sector when the timber is felled (not when it is burned). Clearly, a more uniform accounting would level the field. For instance, a regime where carbon dioxide emissions would have a price, regardless of the fuel burned, and coal sinks would be compensated, would create a uniform price mechanism, where coal and wood biomass would compete on an equal footing with regard to their contribution to actual atmospheric carbon dioxide emissions. These policy issues are, for the most part, outside the purview of local and national legislation, so any initiative for change most likely needs to happen through attention to the more general level danger that the inconsistent accounting and directives pose, as pointed out in [34].

Likewise, as argued in [24], the notion of “renewable energy” functions as a term that somewhat obscures the fact that wood biomass is not a carbon free fuel. A more nuanced research and public discourse is needed, such that combustible and non-combustible forms of energy generation, and carbon-intensive, low-carbon and carbon-free energy systems can be distinguished and discussed in policy settings unambiguously. Our case study corroborates the hypothesis in [24] that the ambiguity of the term “renewable”, as it appears both on the national and EU level discussions, contributes to the potential green paradox.

The DH network itself, with the power plants, pipe networks and consumer equipment, is a massive and expensive piece of infrastructure, where major changes are expensive and slow. If, indeed, it is the case, first, that currently no non-burning technology exists for provisioning for the peak loads, and, second, that transition to a wood biomass base load means a commitment to decades of increased carbon dioxide emissions, then it would make sense to reconsider the social and economic constraints that are behind the need for the peak load. For instance, the need for the peak load could be alleviated by reformulating the contracts between the company and its clients so that the company could provide a lower temperature for some customers during cold periods. It is obvious that such a decrease in the comfort level provided by the service would not be totally welcome by the customers. This brings up the cultural aspect of energy transitions [90] and underlines that a more realistic and detailed understanding of the material path-dependencies and constraints of the legacy infrastructure might help to further the needed steps of transition in terms of social acceptability.

The last point also touches on the role of the city. The city obligates the company, Helen Ltd., to competitive market performance. At the same time, it has set itself the goal of being carbon neutral by 2035. These goals are, to some extent, at cross purposes, in so far as no non-burning technology exists for provisioning for current DH needs at competitive prices. Thus a more realistic and detailed knowledge of the existing DH infrastructure and its constraints would help the city place more realistic demands on the company and itself. If it prioritizes the goal of being carbon free, as it given the current knowledge on climate change and its effects should, it should relax the economic constraints on the company so that it has more leeway in terms of investment and operational costs. If more costly technologies were an option, the green paradox could be easier to avert.

8 Discussion

In so far as there are other DH systems with similar path-dependencies and constraints, the lessons from the case study may apply. This is most likely the case in (Northern) European countries that share the relevant EU regulations and goals, including the ETS system and the RED directive, as well as climatic conditions. This gives grounds to generate a hypothesis on the basis of the case study: in Northern European DH systems that transition away from fossil fuels, especially coal, the path of least resistance points towards burning wood biomass, thus implying a green paradox. This is because the transition to a non-burning alternative implies larger systemic changes (for instance, re-dimensioning of network, reformulating contractual obligations, changing customer expectations, etc.) that are likely to be also more costly.

However, the lessons from the case study are obviously limited by particular constraints in the DH system in Helsinki. First is the bioeconomy framework strongly pushed by the government of PM Sipilä. The bioeconomy framework has helped create a situation favorable to transition to wood biomass, through both direct economic subsidies for wood energy and through encouraging public perception of the benefits of wood biomass use. Here the ambiguity of the term “renewable” has been consequential, not the least by uniting the goals of forest owners and the analyzed NGOs in supporting banning coal, with the expected replacement of coal by wood biomass.

As noted above, the bioeconomy framework has been questioned and criticized by researchers and politicians. It is possible that a future national government may formulate a different strategy, especially if it prioritizes rapid transition, and wood biomass may lose some of its advantage. However, given the weight of the forest sector in Finnish economy, it is unlikely that any national government would set climate or sustainability criteria for wood energy that would be more ambitious than those on the EU level. Consequently, a definitive dismantling of the potential for green paradox in cases like Helsinki DH would most likely demand a change in how GHG emissions from wood burning are included in emission accounting and target setting on the EU and/or global level.

Second, the city as the sole owner of the utility company has created goals that are at cross-purposes: to generate revenue and to transition to carbon neutrality. The city could prioritize carbon neutrality and relax the demand for revenue. Due to the loss of revenue, this would mean increased costs for its citizens. Depending on structures of ownership, this option may not be available in other cases.

Third, the DH network in Helsinki is exceptionally reliable and prepared for undiminished service also during prolonged cold spells. If a DH provider and its customers would be willing to use less heat during cold spells, the peak load demanded from the system would be lower, and consequently provisioning with non-burning alternatives would be easier.

Due to the use of participant observation as a method, some of the results are tied to particular events happening within a given time frame. For instance, the views of the stakeholders, the utility company, politicians and NGOs, are likely to evolve in time, so that a return back to the views present at the time of observation is not possible. Thus the independent verifiability of these observations is necessarily limited. However, the limitation seems acceptable, especially given the fact that the answers to the three research questions rely mostly on publicly available records. The data from participant observation has helped in confirming that the facts presented in the publicly available materials are, indeed, facts on which the stakeholders rely in their views and actions, and in focusing on crucial facts that underlie the positions of the stakeholders.

For instance, the importance of reliability of service and contractual obligations is mentioned in the materials published by Helen Ltd., but observing the argumentation by current and previous representatives of Helen Ltd. helped drive home the centrality of these constraints in the reasoning done in the company. Likewise, discussions with local politicians and representatives of NGOs focused attention to the factors enabling the potential green paradox: in their perspective the potential is an unfortunate side effect of, on one hand, existing international regulation, and, on the other hand, need for rapid and visible action.

9 Conclusion

The DH system in Helsinki has evolved on the basis of cogeneration of heat and electricity from coal burning. The company operating the system is contractually obligated to a given peak load, even during prolonged periods of cold weather, and its customers are accustomed to reliable service. In addition, the owner of the company, the city of Helsinki, expects the company both to be commercially viable in terms of returning a profit to the owner and to provision DH in a carbon neutral manner in line with the goals set by the city and the wider metropolitan area. This, together with a new national legislation banning the burning of coal for energy generation by 2029 means that, at the moment, the most economic and technically reliable option for the company is to start burning wood biomass.

The outcome is unfortunate, as research has shown that GHG emissions from burning wood are higher than from burning coal, at least for a period of several decades, before the “carbon debt” from loggings may be repaid by regenerated woodland. However, this fact, even if observed, is not seen as reason not to use wood biomass by the company, as burning wood biomass is excluded from the EU emission trading system and thus does not, unlike coal, appear in the emission accounting of the company or the city.

In sum, it seems that as hypothesized in the literature, green paradoxes, in the sense of unintended negative consequences of climate policies, are indeed possible, as evidenced by the situation created in Helsinki DH, where regulation aimed at diminishing GHG emissions together with the economic-technological path dependencies of the DH system drive a transition from coal to wood biomass, with the possible effect of increasing atmospheric GHG emissions.

The possibility for the paradox could be undermined by a form of international GHG accounting, for instance on the EU level, that would better unify the accounting of the LULUCF sector (loss of sinks via logging, existing sinks in forests) and the ETS sector. Also, a different ownership policy by the city could provide more economical leeway for the company, so that a more intensive and costly transition would become an option. Third, the task of transition could be made easier if the customers adjusted their levels of expectations on the service, and if this was also reflected in the contracts between the company and its customers.

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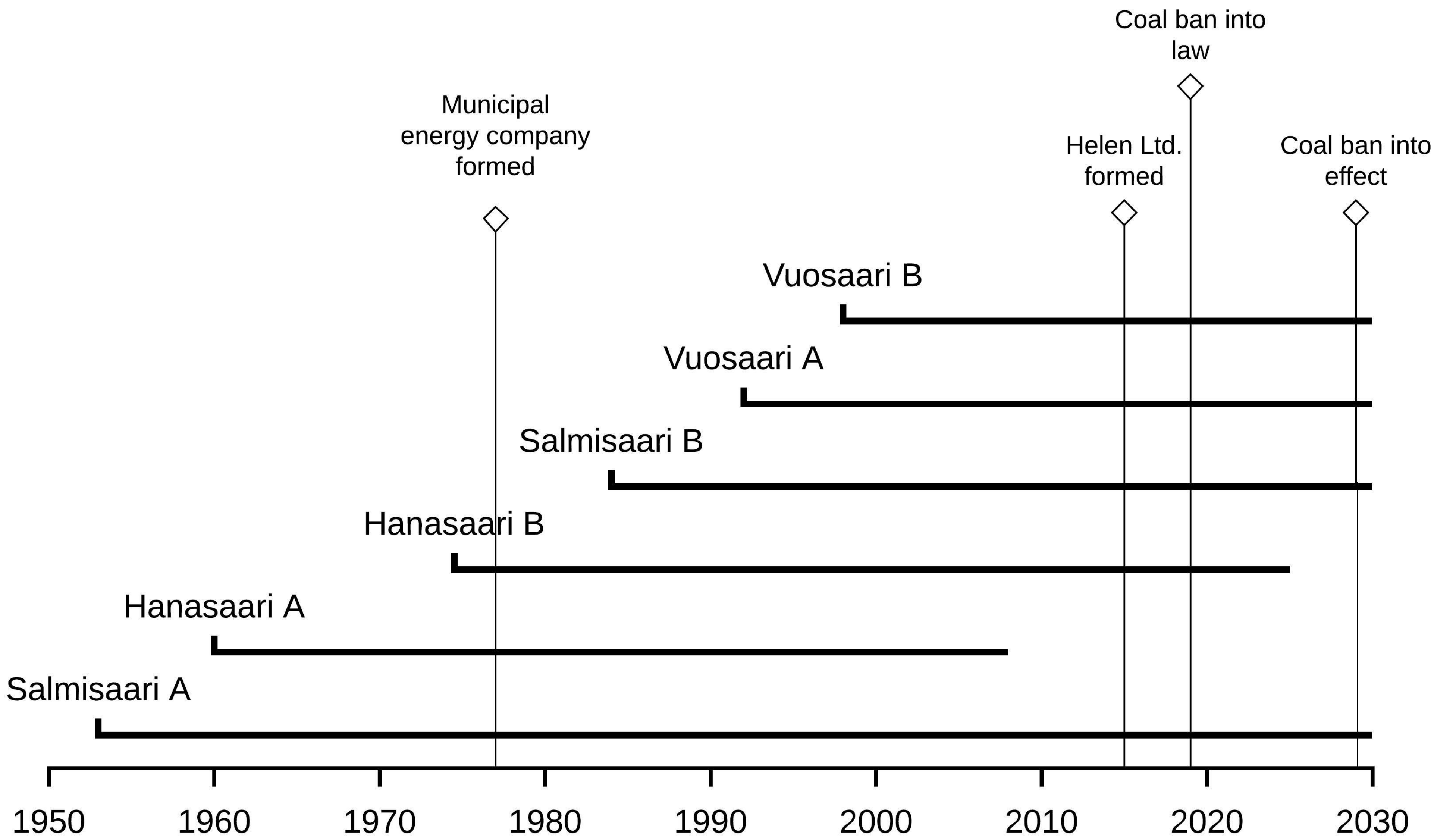
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To continue to burn something? Technological, economic and political path dependencies in district heating in Helsinki, Finland

Supplementary material

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